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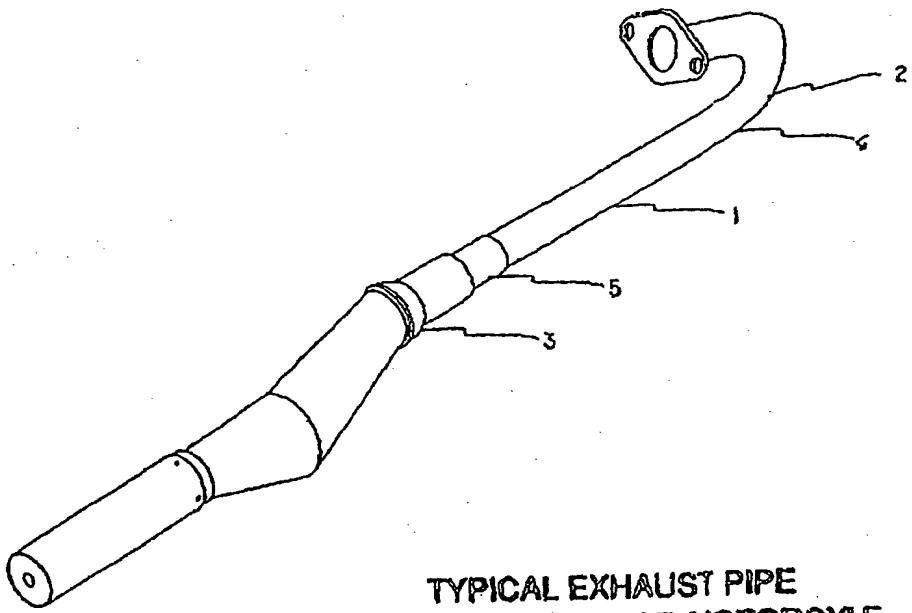

TYPICAL EXHAUST PIPE CONFIGURATION FOR MOTORCYLE

(57) Abstract

A catalytic device (10) that may be installed in a straight section (1) of exhaust pipe (2) from an internal combustion engine without requiring adaptation of the exhaust pipe for acceptance of the device or permanent mounting of the device to the exhaust pipe, a method for making such device and methods of treating exhaust gas from an internal combustion engine using such device.

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EXHAUST PIPE CATALYTIC DEVICE

TECHNICAL FIELD

The present invention relates to a catalytic device that may be inserted into the exhaust line from an internal combustion engine and a method of making such device. In another aspect, the present invention relates to a method for treating exhaust gas from an internal combustion engine with such a device.

BACKGROUND OF THE INVENTION

Gaseous waste products resulting from the combustion of hydrocarbon fuels, such as gasoline and fuel oils, generally include carbon monoxide, hydrocarbons and/or nitrogen oxides. These waste products pose a serious health problem with respect to pollution of the atmosphere. The amount of waste products in such exhaust gases must generally be reduced to levels established by government environmental regulations. Typically, this is done by contacting the exhaust gas stream with catalysts which are capable of removing carbon monoxide, hydrocarbons and nitrogen oxides at the same time. Common practice has been to disperse these catalysts on a high-surface-area substrate of some variety such as pellets, extrudates, spheres, monoliths, etc., which are, in turn, contained in a cannister or vessel located between the exhaust manifold and the atmosphere. This has proven to be an effective and widely used, albeit costly, method for contacting exhaust gas with pollution control catalysts.

A large number of patents have been granted for devices for and methods of contacting exhaust gas with emission control catalyst. U.S. Patent _ 3,598,543 (Crosby *et al.*) teaches a canister containing alumina spheres impregnated with catalyst. U.S. Patent _ 3,503,715 (Haensel) teaches an apparatus for treating an exhaust gas with two different catalysts comprising a vessel with two chambers, each containing a different type of catalytic material dispersed on alumina particles. U.S. Patent _ 3,649,213 (DePalma *et al.*) teaches a V-form catalyst bed in an oval chamber, wherein the bed comprises particles held between two conical screens or perforated baffles. Other patents that teach various reactors holding catalyst beads, pellets. spheres or particles of some sort include U.S. Patent _ 3,911,676

(Jensen), U.S. Patent _ 4,032,310 (Ignoffo), and U.S. Patent _ 4,393,652 (Munro). Some of the many examples of patents using a monolith are U.S. Patent _ 4,094,645 (Bailey), U.S. Patent _ 5,248,859 (Borla) and U.S. Patent _ 5,376,341 (Gulati).

A number of patents has been granted for catalytic devices that employ baffles, screens, diaphragms and the like to hold catalyst in the path of exhaust gas. For example, U.S. Patent _ 5,396,767 (Suzuki) teaches a "jelly-roll-like" structure formed from a flat sheet and a corrugated sheet of foil wound spirally and soldered, the entire structure being then coated with catalytic material and mounted inside a chamber in the exhaust system of a motorcycle.

U.S. Patent _ 5,139,107 (Nagai) teaches a cloth catalyst held between two screens in the form of a cylinder and mounted in a chamber in such a way that exhaust gas passes through the cloth radially.

U.S. Patent _ 5,151,254 (Arai *et al.*) teaches a perforated pipe coated on both its inside and outside surfaces with catalyst and mounted coaxially inside the exhaust pipe from an internal combustion engine. The perforated pipe is formed from two hemispheres that are held in place between flanges in the exhaust pipe.

U.S. Patent _ 5,378,435 (Gavoni) teaches a series of "cup-like" catalyst-coated diaphragms stacked in a chamber in the exhaust system of an internal combustion engine, with the exhaust gas passing through the diaphragms.

U.S. Patent _ 5,386,696 (Prigent *et al.*) teaches an exhaust manifold having a metallic outer tube and a co-axial inner tube, the interior surface of which is coated with catalyst, and an insulator filling the annulus formed between the outer and inner tubes.

And finally, PCT Application _ PCT/EP96/03482 (Reck *et al.*), published as WO 97/07327, teaches a catalytic converter consisting of a jacket pipe to the inside of which metal foils, upon which catalyst has been deposited, have been brazed.

The catalytic elements in all of these devices are permanently mounted, in one fashion or another, inside the exhaust pipe from the vehicle. The net effect of this permanent mounting is to increase the cost of manufacture and installation of this type of device.

SUMMARY OF THE INVENTION

The present invention provides for a catalytic device that may be installed in a straight section of exhaust pipe from an internal combustion engine without requiring

adaptation of the exhaust pipe for acceptance of the device or permanent mounting of the device to the exhaust pipe. In another aspect, the present invention relates to methods for treating exhaust gas from an internal combustion engine with such a device.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG.1 shows a typical exhaust pipe configuration for a motorcycle.

FIG.2 shows the Slotted Cylinder configuration of the present invention.

FIG.3 shows the S-shape configuration of the present invention.

FIG.4 shows several additional-catalytic-surface inserts for the Slotted Cylinder configuration.

FIG.5 shows methods for attachment of additional-catalytic-surface inserts to Slotted Structure.

FIG. 6 shows a typical S-shape configuration having additional catalytic surface.

FIG. 7 shows a double S-shape configuration.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The exhaust pipe from internal combustion engines used in automobiles, motorcycles, trucks, and the like always includes a straight section of pipe. This invention provides for a catalytic device that may be inserted co-axially into that straight section and that is effective in treating such exhaust gases to reduce the amounts of contaminants contained therein to those levels required by government emissions regulations. The catalytic device of the present invention comprises a compressible structure, the surfaces of which that are exposed to exhaust gas being at least partially coated with a catalytic material suitable for achieving the desired exhaust gas treatment, and further characterized in that it fits inside the exhaust pipe straight section. The device is held in position in the exhaust pipe by frictional forces between the outside of the device and the internal surface of the exhaust pipe.

Compressible Structure

A typical exhaust pipe used on a motorcycle is shown in Figure 1. There are probably as many configurations of exhaust pipes as there are automobile, motorcycle and truck designs. However, each configuration employs a straight section or can be designed to incorporate such. The exhaust pipe shown on Figure 1 contains a straight section 1 and

curved (or angled)sections 2 and 3 connecting to straight section 1 at its inlet end 4 and outlet end 5, respectively. The catalytic device of the present invention is inserted into straight section 1. For simplicity, the exhaust pipe shown in all figures have been shown to have a circular cross section, which is the cross section most commonly employed; it is readily apparent that all of the illustrative designs shown herein may be adapted to exhaust pipes having non-circular cross-section.

Self-Retaining Feature

A key element of the present invention is the catalytic device's being retained in position within a straight section of an exhaust pipe without the need for any sort of permanent attachment thereto. No welding, brazing, bolting or flanging of the device to the exhaust pipe is necessary to retain the catalytic device in position. Instead, the catalytic device relies on frictional forces between the outside surfaces of the device and the interior surface of the exhaust pipe to retain the device in position. This frictional force may be enhanced by providing a roughened surface finish on the outside surface of the catalytic device, the interior surface of the exhaust pipe, or both. This approach reduces the costs associated with manufacture and assembly of the exhaust system. The catalytic device of the present invention may be installed into previously used exhaust systems, either to provide catalytic conversion to an exhaust system that did not previously employ such or to replace an existing converter. Alternatively, the catalytic device may be installed during the original manufacture of an exhaust system, either after the exhaust pipe has been formed or prior to bending the exhaust pipe.

Either of two structural configurations make this "self-retaining" feature possible. Figure 2 shows the preferred "slotted-cylinder" configuration and Figure 3 shows the "S-shaped" configuration. In Figure 2, cylinder 10 having an outside diameter D contains a slot 11 of width d extending the entire length of cylinder 10. Cylinder 10 is constructed of a material that permits cylinder 10 to be temporarily compressed but to return to its original shape when the compressive force is removed. Outside diameter D is slightly larger than the diameter of the interior surface of the exhaust pipe into which Slotted Cylinder 10 is to be inserted. Slot width d is sized to permit Slotted Cylinder 10 to be compressed radially so that it can be inserted into said exhaust pipe. When such compressive force is released, Slotted Cylinder 10, in attempting to return to its original outside diameter D, is constrained by the

interior surface of the exhaust pipe into which it has been inserted, thereby producing a friction force between the exterior surface 12 of Slotted Cylinder 10 and the interior surface of the exhaust pipe into which it has been inserted. This friction force holds Slotted Cylinder 10 in the position in the exhaust pipe into which it has been so placed.

In Figure 3, S-shape 20 has an outside dimension D slightly larger than the diameter of the interior surface of the exhaust pipe into which S-shape 20 is to be inserted. Also like Slotted Cylinder 10, S-shape 20 is constructed of a material that permits it to being temporarily compressed in the direction shown on Figure 3 but to return to its original shape when the compressive force is removed, thereby permitting it to be inserted into the exhaust pipe and retained in position by the friction force between its external surfaces 21 and 22 and the interior surface of the exhaust pipe.

A variation on the S-shape configuration is the Double S-shape as shown in Figure 7. The same principles apply to this configuration as to the S-shape.

The preferred construction materials are corrosion- and heat-resistant steels, particularly ferritic and austenitic stainless steels, and such steels containing aluminum are particularly preferred.

The structures and inserts discussed below may be formed by any of the methods known to those skilled in the art.

Additional Catalytic Surface Inserts

The compressible structures shown in Figures 2 and 3 have a limited amount of internal surface upon which a catalytic coating may be placed in contact with the exhaust gas to be treated. This invention also provides means by which the amount of such surface may be increased for those applications that would benefit therefrom. Inserts, usually constructed of the same material as employed for the compressible structure, may be used to increase the surface area in contact with the exhaust gas passing through the device.

Figure 4 shows some of the many conceivable types of inserts that may be included with the Slotted Cylinder of Figure 2. In A of Figure 4, tube 30 having perforations and an outside diameter smaller than the internal diameter of the Slotted Cylinder is mounted coaxially inside of Slotted Cylinder 10. The perforations shown in tube 30 are, of course, optional and are shown to represent one of many possible surface area and mass transfer

enhancements. Alternatively, tube 30 may not have perforations or may be fitted with fins, baffles or studs oriented in a number of ways relative to the flow path of the exhaust gas.

Figure 5 shows some of the methods by which tube 30 may be attached to the inside surface of Slotted Cylinder 10. In A of Figure 5, tube 30 is mounted inside of and coaxially with Slotted Cylinder 10 through the use of bars 31 that extend the entire length of tube 30 and are welded to the exterior surface 32 of tube 30 and to the inside surface 13 of Slotted Cylinder 10 at a point sufficiently distant from slot 11 to allow for compression of Slotted Cylinder 10 and insertion into the exhaust pipe straight section 1. Two variations on the use of bars extending the length of tube 30 to attach tube 30 inside of and coaxially with Slotted Cylinder 10 are shown in B and D of Figure 5. In C of Figure 5, tube 30 is elastically centered and held inside of and coaxially with Slotted Cylinder 10 through the use of two elastic metal strips 35, extending the length of tube 30, welded to opposing sides of tube 30 and bearing on the inside surface 13 of Slotted Cylinder 10.

B and C of Figure 4 show two of the many additional surface area enhancements that may be added to tube 30 shown in A of Figure 4. In B another tube 35 is mounted coaxially inside of tube 30 and in C crossed metal bars 36 are so mounted. These metal bars may run straight through the length of tube 30 or may be periodically indexed along tube 30's length to promote increased turbulence of the exhaust gas flow. In D of Figure 4, increased surface area is accomplished by inclusion of crossed metal bars 37 inside of and extending the length of Slotted Cylinder 10 welded to the inside surface 13 at points 38, that is, opposed to slot 11.

Figure 6 shows one of the many conceivable ways additional surface area may be included with the S-Shape device of Figure 3. The perforations shown are, of course, optional. Alternatively the S-Shape device may be fitted with fins, baffles or studs oriented in a number of ways relative to the flow path of the exhaust gas.

Preparation of Surface to accept Catalytic Coating

The compressible structure's internal surfaces to which a catalytic coating is to be applied should be treated to insure proper application and adhesion of the coating. After formation of the structure. including attachment of an insert if employed, it should be heated in a chloride-free oven to drive off any residual oils or organic compounds that may remain from the forming, machining and handling steps associated with its manufacture. Subsequent

contact of the device with chlorides should be avoided to reduce the potential for any corrosion of the structure's surfaces.

Catalytic Coating

Any catalytic coating suitable for catalyzing the desired conversion of harmful components of the exhaust gas to be treated may be applied to the compressible structure by any of a number of means known to those skilled in the art, including spraying, dipping, etc., with dipping followed by wiping from the structure's outside surface whatever catalytic material may have adhered thereto. If noble metals are to be included in the coating, it is important that the precursors of such noble metals not be chlorides. A number of precursor compounds, including nitrates and sulfur-based compounds, are acceptable, with nitrates being preferred.

Performance

Tests of the catalytic device's ability to reduce harmful emissions show performance comparable to that exhibited by the device taught by Reck *et al.* in WO 97/07327. These tests are described in Examples 1-3 below. Each of the devices tested in these examples contained the same amount of catalytic coating and noble metal. The differences in performance illustrate that reduction in hydrocarbon, nitrogen oxide and carbon monoxide emissions is a function of the efficiency of mass transfer between the exhaust gas and the catalyzed surface, which, in turn, is dependent on the geometry of the device used.

EXAMPLE 1
(Comparative)

A device representative of that taught by Reck *et al.* in WO 97/07327 was manufactured to contain one layer of corrugated aluchrome foil brazed inside a 30 mm diameter tube. The corrugated layer of aluchrome foil was 65 mm long and had sinusoidal corrugations with an amplitude of 6 mm and period of 10 mm.

After removing residual oils and organic compounds left from forming procedures by heating the device in an oven, the internal surface of the device was coated with 0.55 grams of an alumina/ceria composition in which the ratio of alumina to ceria was 2.4 and then with 0.12 grams of platinum plus rhodium in a ratio of 5 to 1.

The performance of the catalytic device was evaluated by mounting the device in the exhaust pipe of a 110 cm^3 -displacement motorcycle and measuring emissions using the India Driving Cycle. Hydrocarbon plus nitrogen oxide and carbon monoxide emissions were measured to be 2.6 grams per km and 1.7 grams per km, respectively, versus uncontrolled emissions of 3.9 grams per km and 3.1 grams per km, respectively, determined by subjecting the same motorcycle to the same driving cycle.

EXAMPLE 2

A simple slotted-cylinder catalytic device of the present invention (of the type shown in Figure 2) was manufactured, cleaned, and its inside surface coated with the same amount and composition of coating and noble metals as in Example 1. The device had a length of 85 mm and a diameter of 30 mm. Its performance was evaluated using the same procedure as used in Example 1. Hydrocarbon plus nitrogen oxide and carbon monoxide emissions were measured to be 3.1 grams per km and 2.4 grams per km, respectively, versus uncontrolled emissions of 3.8 grams per km and 3.3 grams per km, respectively, determined by subjecting the same motorcycle to the same driving cycle.

EXAMPLE 3

A slotted-cylinder catalytic device of the present invention having a dual radial insert (of the type shown in Figure 4, view B) was manufactured, cleaned, and its inside surface coated with the same amount and composition of coating and noble metals as in Example 1. The device had a length of 90 mm and a diameter of 30 mm. Its performance was evaluated using the same procedure as used in Example 1. Hydrocarbon plus nitrogen oxide and carbon monoxide emissions were measured to be 2.0 grams per km and 1.9 grams per km, respectively, versus uncontrolled emissions of 3.8 grams per km and 3.3 grams per km, respectively, determined by subjecting the same motorcycle to the same driving cycle.

CLAIMS

1. A catalytic device suitable for treating exhaust gas from an internal combustion engine having an exhaust pipe, said pipe containing at least one straight section having an inner surface having a fixed radial dimension, comprising a structure having an interior surface and an outer surface which outer surface has a radial outside dimension greater than said straight section inner surface's fixed radial dimension, which radial outside dimension may be temporarily reduced by applying an external radial compressive force thereby permitting the structure to be inserted into said straight section, and which structure relaxes when the compressive force is removed thereby causing the structure's outer surface to contact the straight section inner surface thereby creating a friction force between the structure's outer surface and the straight section inner surface, which force acts to hold the structure coaxially inside the straight section and wherein said interior surface is at least partially coated with a catalytic material that is effective for treating said exhaust gas.

2. The catalytic device of Claim 1 wherein the straight section is round and the structure is a cylinder having a slot extending the cylinder's entire length.

3. The catalytic device of Claim 1 wherein the structure has an S-shaped cross section.

4. The catalytic device of Claim 1 wherein the straight section and the structure each have an oval cross section and the structure has a slot extending its entire length.

5. The catalytic device of Claim 1 wherein the structure contains at least one insert that provides additional surface area, said insert being fixedly connected to said structure's interior surface.

6. The catalytic device of Claim 1 wherein the structure contains at least one insert that provides additional surface area, said insert being fixedly connected to said structure's interior surface and being further characterized in that the insert contains perforations.

7. The catalytic device of Claim 1 wherein the structure is made of a metal selected from the group consisting of ferritic and austenitic stainless steels.

8. The catalytic device of Claim 1 made by a process comprising forming the structure from a steel selected from the class consisting of ferritic and austenitic steels, heating the structure, thereby driving off any oils or organic compounds that might remain on the structure after said forming and then applying the catalytic material by a method selected from the class consisting of a) dipping the structure into a solution of catalytic material and then wiping said outside surface clean and b) dipping the structure into a solution of catalytic material, allowing the solution to dry and then mechanically removing the dried solution from said outside surface.

9. A method for treating exhaust gas from an internal combustion engine having an exhaust pipe containing a straight section comprising inserting the catalytic device of Claim 1 into said straight section.

10. The method of Claim 9 wherein the engine is used to power a motor vehicle selected from the group consisting of motorcycles, automobiles, trucks, busses and tractors.

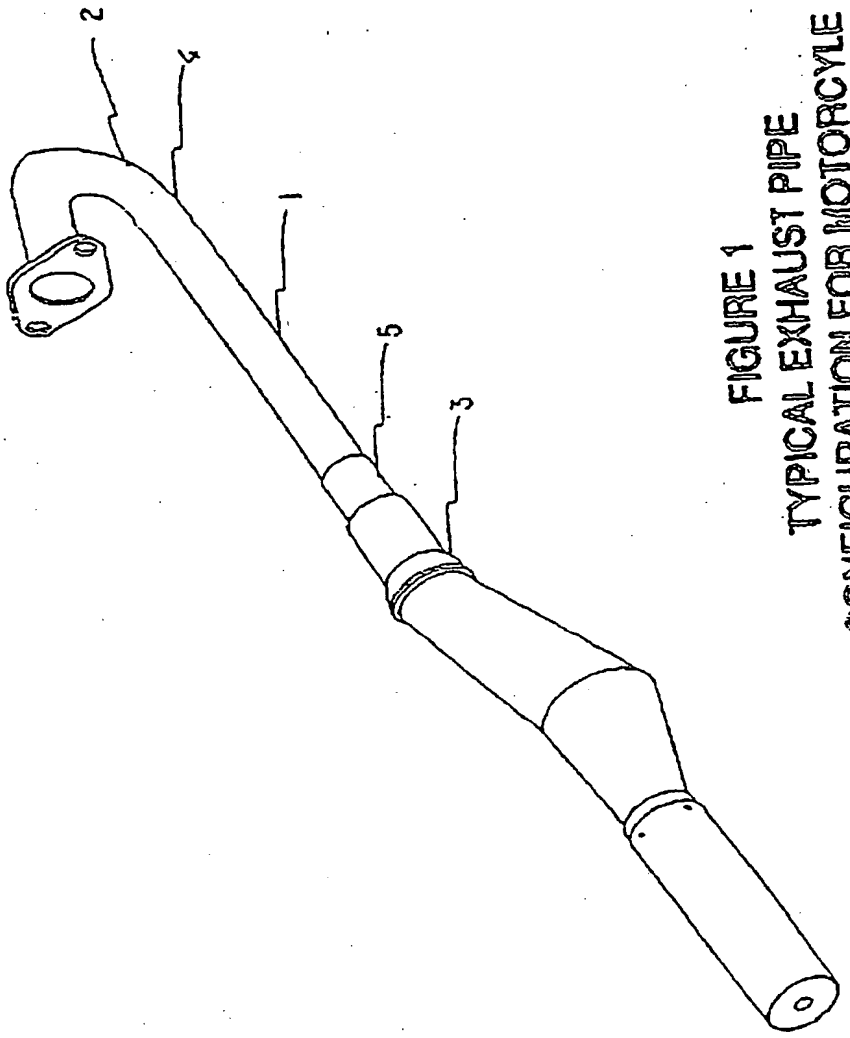


FIGURE 1
TYPICAL EXHAUST PIPE
CONFIGURATION FOR MOTORCYLE

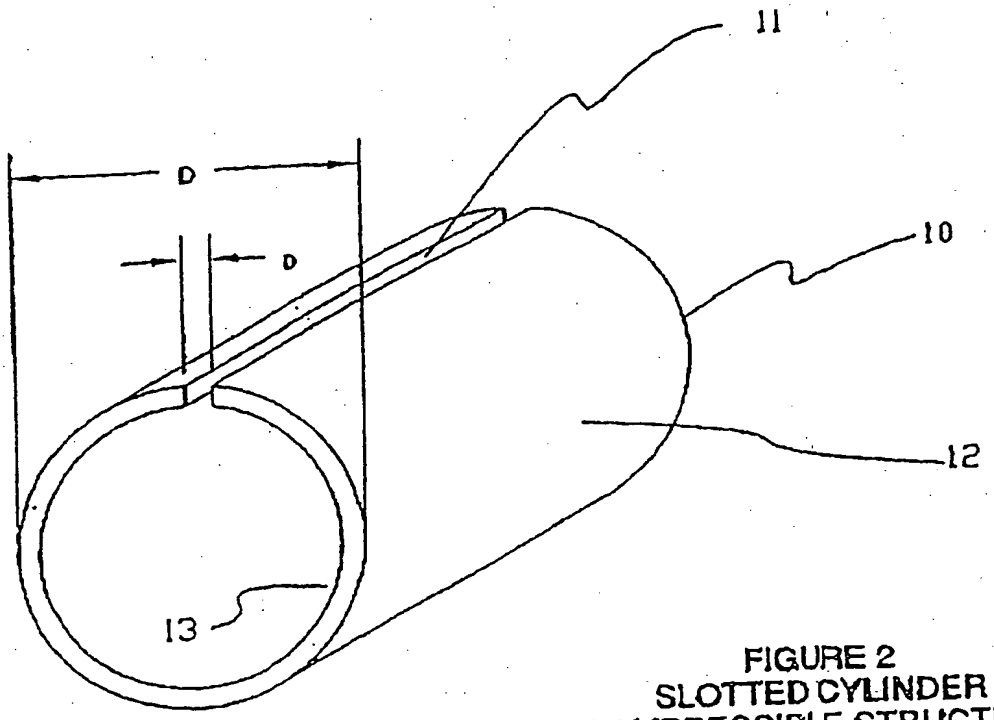


FIGURE 2
SLOTTED CYLINDER
COMPRESSIBLE STRUCTURE

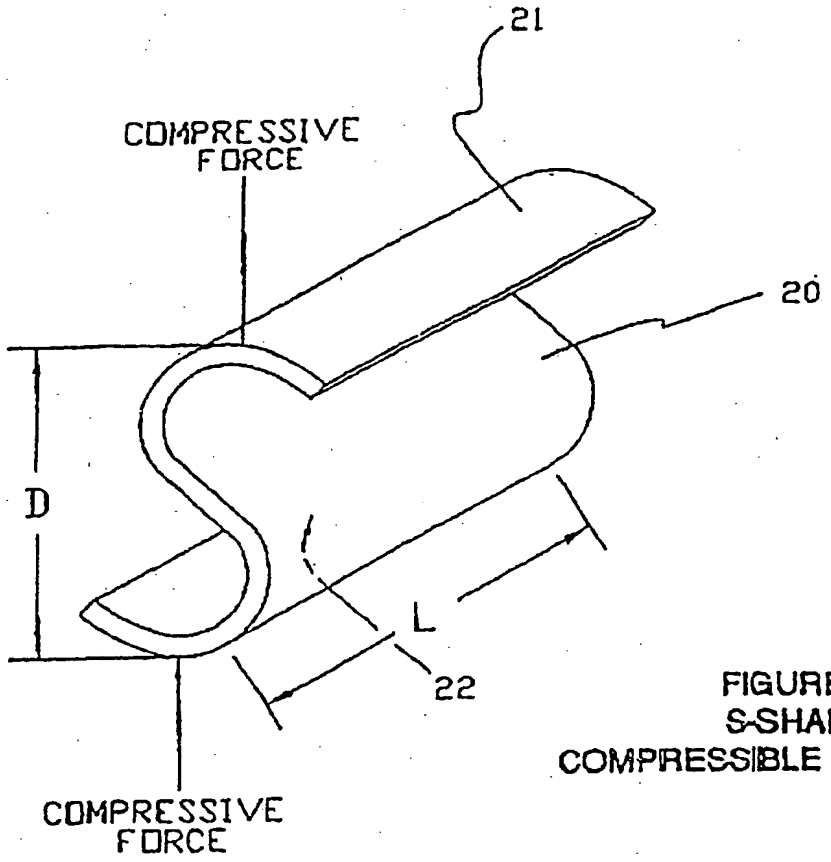


FIGURE 3
S-SHAPE
COMPRESSIBLE STRUCTURE

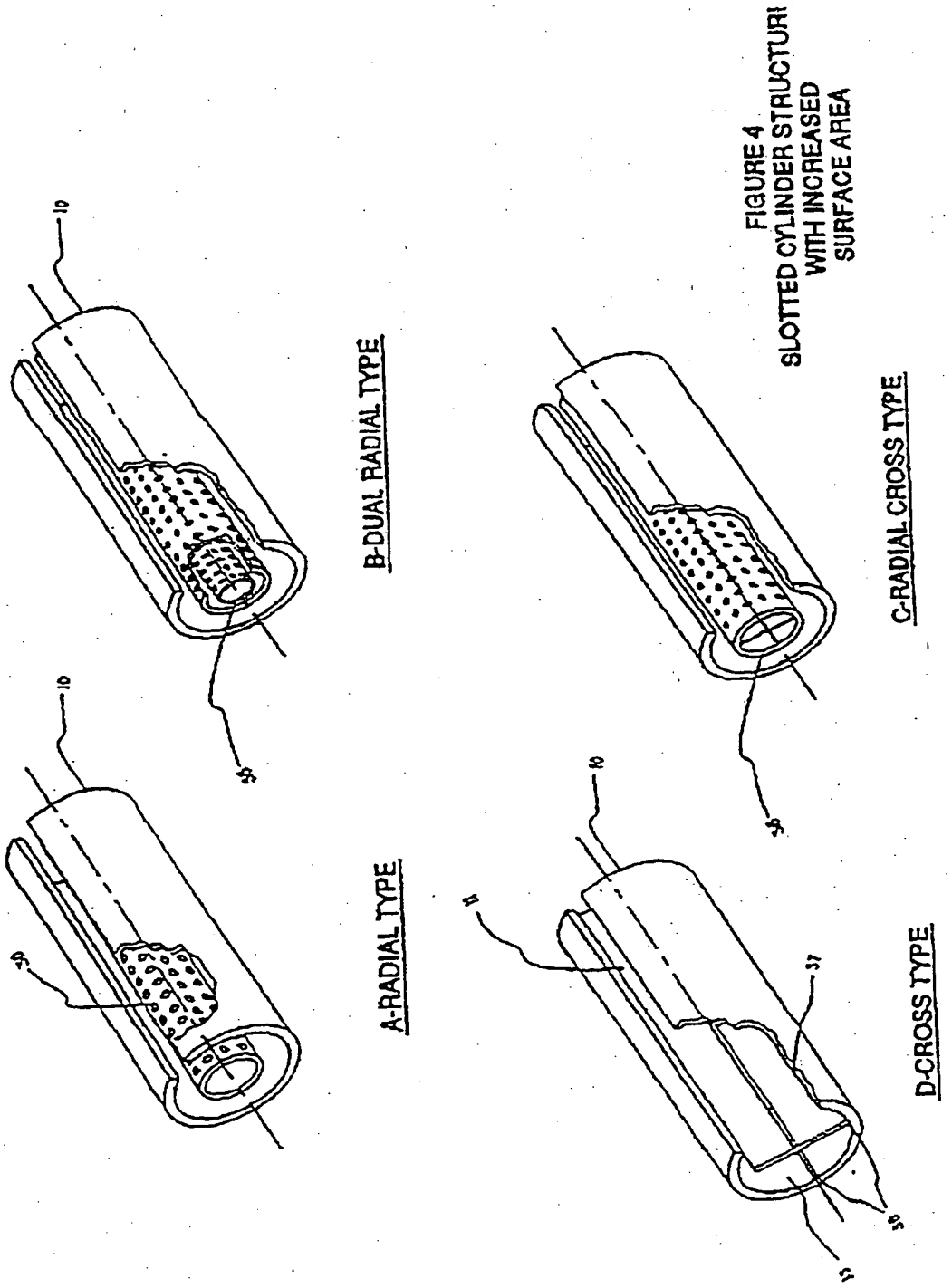


FIGURE 4
SLOTTED CYLINDER STRUCTURE WITH INCREASED SURFACE AREA

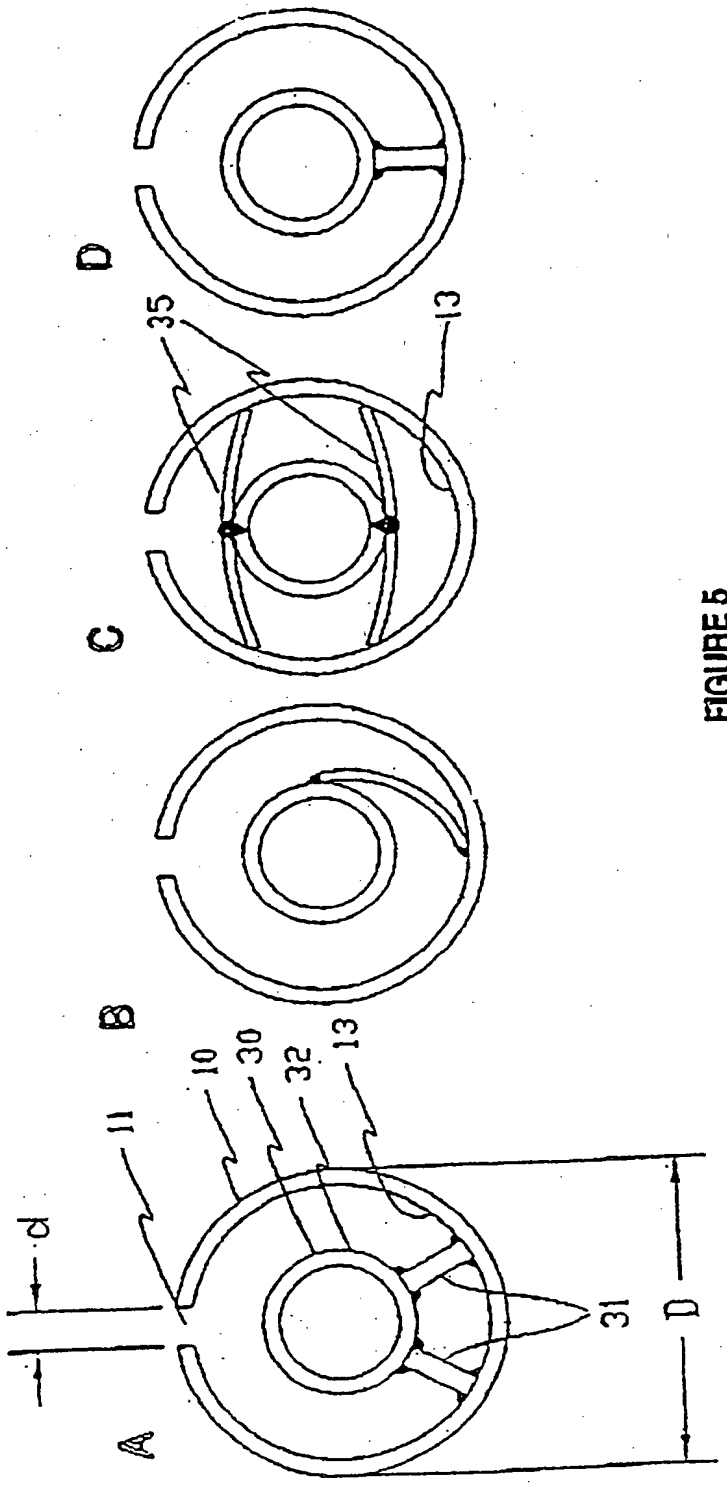
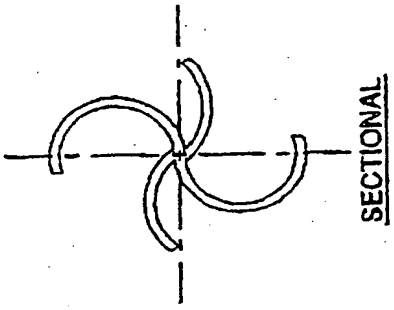


FIGURE 5
SOME METHODS FOR ATTACHMENT
OF ADDITIONAL CATALYTIC SURFACE INSERTS
TO SLOTTED CYLINDER COMPRESSIBLE STRUCTURE



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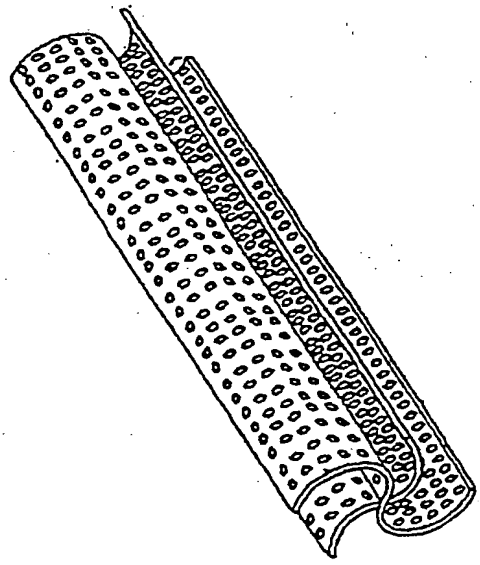
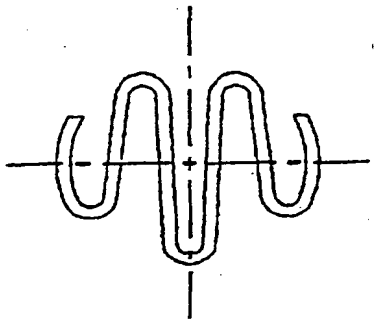


S-FORM WITH FINS TYPE

FIGURE 6
S-FORM WITH ADDITIONAL SURFACE



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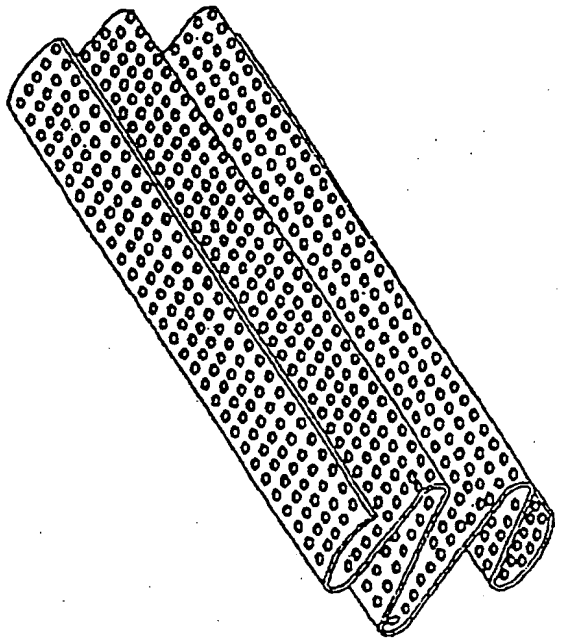

DOUBLE S TYPE

FIGURE 7
DOUBLE S SHAPE

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 99/13178

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 F01N3/28

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 F01N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 095, no. 003, 28 April 1995 (1995-04-28) & JP 06 343876 A (YAMAHA MOTOR CO LTD), 20 December 1994 (1994-12-20)	1,3,5,6, 9,10
Y	abstract ---	2,4
Y	US 5 724 735 A (MONTALBANO ANDREW J ET AL) 10 March 1998 (1998-03-10) column 2, line 2 - line 35 column 3, line 37 -column 4, line 13 figures 3-5 ---	2,4
A	EP 0 480 082 A (NIPPON STEEL CORP) 15 April 1992 (1992-04-15) page 3, column 54 -page 4, column 29 figures 1-5 --- -/--	1

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
22 September 1999	29/09/1999

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Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

International Application No
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 492 878 A (FUJII JUN ET AL) 20 February 1996 (1996-02-20) column 2, line 30 -column 3, line 35	8

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

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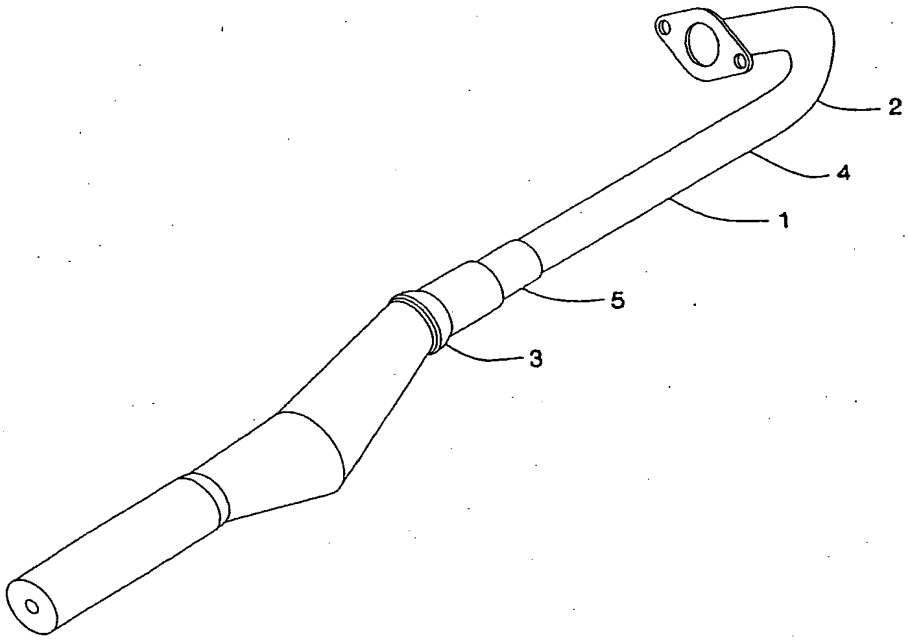

(57) Abstract

A catalytic device (10) that may be installed in a straight section (1) of exhaust pipe (2) from an internal combustion engine without requiring adaptation of the exhaust pipe for acceptance of the device or permanent mounting of the device to the exhaust pipe, a method for making such device and methods of treating exhaust gas from an internal combustion engine using such device.

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EXHAUST PIPE CATALYTIC DEVICE

TECHNICAL FIELD

The present invention relates to a catalytic device that may be inserted into the exhaust line from an internal combustion engine and a method of making such device. In another aspect, the present invention relates to a method for treating exhaust gas from an internal combustion engine with such a device.

BACKGROUND OF THE INVENTION

Gaseous waste products resulting from the combustion of hydrocarbon fuels, such as gasoline and fuel oils, generally include carbon monoxide, hydrocarbons and/or nitrogen oxides. These waste products pose a serious health problem with respect to pollution of the atmosphere. The amount of waste products in such exhaust gases must generally be reduced to levels established by government environmental regulations. Typically, this is done by contacting the exhaust gas stream with catalysts which are capable of removing carbon monoxide, hydrocarbons and nitrogen oxides at the same time. Common practice has been to disperse these catalysts on a high-surface-area substrate of some variety such as pellets, extrudates, spheres, monoliths, etc., which are, in turn, contained in a cannister or vessel located between the exhaust manifold and the atmosphere. This has proven to be an effective and widely used, albeit costly, method for contacting exhaust gas with pollution control catalysts.

A large number of patents have been granted for devices for and methods of contacting exhaust gas with emission control catalyst. U.S. Patent _ 3,598,543 (Crosby *et al.*) teaches a canister containing alumina spheres impregnated with catalyst. U.S. Patent _ 3,503,715 (Haensel) teaches an apparatus for treating an exhaust gas with two different catalysts comprising a vessel with two chambers, each containing a different type of catalytic material dispersed on alumina particles. U.S. Patent _ 3,649,213 (DePalma *et al.*) teaches a V-form catalyst bed in an oval chamber, wherein the bed comprises particles held between two conical screens or perforated baffles. Other patents that teach various reactors holding catalyst beads, pellets. spheres or particles of some sort include U.S. Patent _ 3,911,676.

(Jensen), U.S. Patent _ 4,032,310 (Ignoffo), and U.S. Patent _ 4,393,652 (Munro). Some of the many examples of patents using a monolith are U.S. Patent _ 4,094,645 (Bailey), U.S. Patent _ 5,248,859 (Borla) and U.S. Patent _ 5,376,341 (Gulati).

A number of patents has been granted for catalytic devices that employ baffles, screens, diaphragms and the like to hold catalyst in the path of exhaust gas. For example, U.S. Patent _ 5,396,767 (Suzuki) teaches a "jelly-roll-like" structure formed from a flat sheet and a corrugated sheet of foil wound spirally and soldered, the entire structure being then coated with catalytic material and mounted inside a chamber in the exhaust system of a motorcycle.

U.S. Patent _ 5,139,107 (Nagai) teaches a cloth catalyst held between two screens in the form of a cylinder and mounted in a chamber in such a way that exhaust gas passes through the cloth radially.

U.S. Patent _ 5,151,254 (Arai *et al.*) teaches a perforated pipe coated on both its inside and outside surfaces with catalyst and mounted coaxially inside the exhaust pipe from an internal combustion engine. The perforated pipe is formed from two hemispheres that are held in place between flanges in the exhaust pipe.

U.S. Patent _ 5,378,435 (Gavoni) teaches a series of "cup-like" catalyst-coated diaphragms stacked in a chamber in the exhaust system of an internal combustion engine, with the exhaust gas passing through the diaphragms.

U.S. Patent _ 5,386,696 (Prigent *et al.*) teaches an exhaust manifold having a metallic outer tube and a co-axial inner tube, the interior surface of which is coated with catalyst, and an insulator filling the annulus formed between the outer and inner tubes.

And finally, PCT Application _ PCT/EP96/03482 (Reck *et al.*), published as WO 97/07327, teaches a catalytic converter consisting of a jacket pipe to the inside of which metal foils, upon which catalyst has been deposited, have been brazed.

The catalytic elements in all of these devices are permanently mounted, in one fashion or another, inside the exhaust pipe from the vehicle. The net effect of this permanent mounting is to increase the cost of manufacture and installation of this type of device.

SUMMARY OF THE INVENTION

The present invention provides for a catalytic device that may be installed in a straight section of exhaust pipe from an internal combustion engine without requiring

adaptation of the exhaust pipe for acceptance of the device or permanent mounting of the device to the exhaust pipe. In another aspect, the present invention relates to methods for treating exhaust gas from an internal combustion engine with such a device.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG.1 shows a typical exhaust pipe configuration for a motorcycle.

FIG.2 shows the Slotted Cylinder configuration of the present invention.

FIG.3 shows the S-shape configuration of the present invention.

FIG.4 shows several additional-catalytic-surface inserts for the Slotted Cylinder configuration.

FIG.5 shows methods for attachment of additional-catalytic-surface inserts to Slotted Structure.

FIG. 6 shows a typical S-shape configuration having additional catalytic surface.

FIG. 7 shows a double S-shape configuration.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The exhaust pipe from internal combustion engines used in automobiles, motorcycles, trucks, and the like always includes a straight section of pipe. This invention provides for a catalytic device that may be inserted co-axially into that straight section and that is effective in treating such exhaust gases to reduce the amounts of contaminants contained therein to those levels required by government emissions regulations. The catalytic device of the present invention comprises a compressible structure, the surfaces of which that are exposed to exhaust gas being at least partially coated with a catalytic material suitable for achieving the desired exhaust gas treatment, and further characterized in that it fits inside the exhaust pipe straight section. The device is held in position in the exhaust pipe by frictional forces between the outside of the device and the internal surface of the exhaust pipe.

Compressible Structure

A typical exhaust pipe used on a motorcycle is shown in Figure 1. There are probably as many configurations of exhaust pipes as there are automobile, motorcycle and truck designs. However, each configuration employs a straight section or can be designed to incorporate such. The exhaust pipe shown on Figure 1 contains a straight section 1 and

curved (or angled)sections 2 and 3 connecting to straight section 1 at its inlet end 4 and outlet end 5, respectively. The catalytic device of the present invention is inserted into straight section 1. For simplicity, the exhaust pipe shown in all figures have been shown to have a circular cross section, which is the cross section most commonly employed; it is readily apparent that all of the illustrative designs shown herein may be adapted to exhaust pipes having non-circular cross-section.

Self-Retaining Feature

A key element of the present invention is the catalytic device's being retained in position within a straight section of an exhaust pipe without the need for any sort of permanent attachment thereto. No welding, brazing, bolting or flanging of the device to the exhaust pipe is necessary to retain the catalytic device in position. Instead, the catalytic device relies on frictional forces between the outside surfaces of the device and the interior surface of the exhaust pipe to retain the device in position. This frictional force may be enhanced by providing a roughened surface finish on the outside surface of the catalytic device, the interior surface of the exhaust pipe, or both. This approach reduces the costs associated with manufacture and assembly of the exhaust system. The catalytic device of the present invention may be installed into previously used exhaust systems, either to provide catalytic conversion to an exhaust system that did not previously employ such or to replace an existing converter. Alternatively, the catalytic device may be installed during the original manufacture of an exhaust system, either after the exhaust pipe has been formed or prior to bending the exhaust pipe.

Either of two structural configurations make this "self-retaining" feature possible. Figure 2 shows the preferred "slotted-cylinder" configuration and Figure 3 shows the "S-shaped" configuration. In Figure 2, cylinder 10 having an outside diameter D contains a slot 11 of width d extending the entire length of cylinder 10. Cylinder 10 is constructed of a material that permits cylinder 10 to be temporarily compressed but to return to its original shape when the compressive force is removed. Outside diameter D is slightly larger than the diameter of the interior surface of the exhaust pipe into which Slotted Cylinder 10 is to be inserted. Slot width d is sized to permit Slotted Cylinder 10 to be compressed radially so that it can be inserted into said exhaust pipe. When such compressive force is released, Slotted Cylinder 10, in attempting to return to its original outside diameter D, is constrained by the

interior surface of the exhaust pipe into which it has been inserted, thereby producing a friction force between the exterior surface 12 of Slotted Cylinder 10 and the interior surface of the exhaust pipe into which it has been inserted. This friction force holds Slotted Cylinder 10 in the position in the exhaust pipe into which it has been so placed.

In Figure 3, S-shape 20 has an outside dimension D slightly larger than the diameter of the interior surface of the exhaust pipe into which S-shape 20 is to be inserted. Also like Slotted Cylinder 10, S-shape 20 is constructed of a material that permits it to being temporarily compressed in the direction shown on Figure 3 but to return to its original shape when the compressive force is removed, thereby permitting it to be inserted into the exhaust pipe and retained in position by the friction force between its external surfaces 21 and 22 and the interior surface of the exhaust pipe.

A variation on the S-shape configuration is the Double S-shape as shown in Figure 7. The same principles apply to this configuration as to the S-shape.

The preferred construction materials are corrosion- and heat-resistant steels, particularly ferritic and austenitic stainless steels, and such steels containing aluminum are particularly preferred.

The structures and inserts discussed below may be formed by any of the methods known to those skilled in the art.

Additional Catalytic Surface Inserts

The compressible structures shown in Figures 2 and 3 have a limited amount of internal surface upon which a catalytic coating may be placed in contact with the exhaust gas to be treated. This invention also provides means by which the amount of such surface may be increased for those applications that would benefit therefrom. Inserts, usually constructed of the same material as employed for the compressible structure, may be used to increase the surface area in contact with the exhaust gas passing through the device.

Figure 4 shows some of the many conceivable types of inserts that may be included with the Slotted Cylinder of Figure 2. In A of Figure 4, tube 30 having perforations and an outside diameter smaller than the internal diameter of the Slotted Cylinder is mounted coaxially inside of Slotted Cylinder 10. The perforations shown in tube 30 are, of course, optional and are shown to represent one of many possible surface area and mass transfer

enhancements. Alternatively, tube 30 may not have perforations or may be fitted with fins, baffles or studs oriented in a number of ways relative to the flow path of the exhaust gas.

Figure 5 shows some of the methods by which tube 30 may be attached to the inside surface of Slotted Cylinder 10. In A of Figure 5, tube 30 is mounted inside of and coaxially with Slotted Cylinder 10 through the use of bars 31 that extend the entire length of tube 30 and are welded to the exterior surface 32 of tube 30 and to the inside surface 13 of Slotted Cylinder 10 at a point sufficiently distant from slot 11 to allow for compression of Slotted Cylinder 10 and insertion into the exhaust pipe straight section 1. Two variations on the use of bars extending the length of tube 30 to attach tube 30 inside of and coaxially with Slotted Cylinder 10 are shown in B and D of Figure 5. In C of Figure 5, tube 30 is elastically centered and held inside of and coaxially with Slotted Cylinder 10 through the use of two elastic metal strips 35, extending the length of tube 30, welded to opposing sides of tube 30 and bearing on the inside surface 13 of Slotted Cylinder 10.

B and C of Figure 4 show two of the many additional surface area enhancements that may be added to tube 30 shown in A of Figure 4. In B another tube 35 is mounted coaxially inside of tube 30 and in C crossed metal bars 36 are so mounted. These metal bars may run straight through the length of tube 30 or may be periodically indexed along tube 30's length to promote increased turbulence of the exhaust gas flow. In D of Figure 4, increased surface area is accomplished by inclusion of crossed metal bars 37 inside of and extending the length of Slotted Cylinder 10 welded to the inside surface 13 at points 38, that is, opposed to slot 11.

Figure 6 shows one of the many conceivable ways additional surface area may be included with the S-Shape device of Figure 3. The perforations shown are, of course, optional. Alternatively the S-Shape device may be fitted with fins, baffles or studs oriented in a number of ways relative to the flow path of the exhaust gas.

Preparation of Surface to accept Catalytic Coating

The compressible structure's internal surfaces to which a catalytic coating is to be applied should be treated to insure proper application and adhesion of the coating. After formation of the structure, including attachment of an insert if employed, it should be heated in a chloride-free oven to drive off any residual oils or organic compounds that may remain from the forming, machining and handling steps associated with its manufacture. Subsequent

contact of the device with chlorides should be avoided to reduce the potential for any corrosion of the structure's surfaces.

Catalytic Coating

Any catalytic coating suitable for catalyzing the desired conversion of harmful components of the exhaust gas to be treated may be applied to the compressible structure by any of a number of means known to those skilled in the art, including spraying, dipping, etc., with dipping followed by wiping from the structure's outside surface whatever catalytic material may have adhered thereto. If noble metals are to be included in the coating, it is important that the precursors of such noble metals not be chlorides. A number of precursor compounds, including nitrates and sulfur-based compounds, are acceptable, with nitrates being preferred.

Performance

Tests of the catalytic device's ability to reduce harmful emissions show performance comparable to that exhibited by the device taught by Reck *et al.* in WO 97/07327. These tests are described in Examples 1-3 below. Each of the devices tested in these examples contained the same amount of catalytic coating and noble metal. The differences in performance illustrate that reduction in hydrocarbon, nitrogen oxide and carbon monoxide emissions is a function of the efficiency of mass transfer between the exhaust gas and the catalyzed surface, which, in turn, is dependent on the geometry of the device used.

EXAMPLE 1
(Comparative)

A device representative of that taught by Reck *et al.* in WO 97/07327 was manufactured to contain one layer of corrugated aluchrome foil brazed inside a 30 mm diameter tube. The corrugated layer of aluchrome foil was 65 mm long and had sinusoidal corrugations with an amplitude of 6 mm and period of 10 mm.

After removing residual oils and organic compounds left from forming procedures by heating the device in an oven, the internal surface of the device was coated with 0.55 grams of an alumina/ceria composition in which the ratio of alumina to ceria was 2.4 and then with 0.12 grams of platinum plus rhodium in a ratio of 5 to 1.

The performance of the catalytic device was evaluated by mounting the device in the exhaust pipe of a 110 cm^3 -displacement motorcycle and measuring emissions using the India Driving Cycle. Hydrocarbon plus nitrogen oxide and carbon monoxide emissions were measured to be 2.6 grams per km and 1.7 grams per km, respectively, versus uncontrolled emissions of 3.9 grams per km and 3.1 grams per km, respectively, determined by subjecting the same motorcycle to the same driving cycle.

EXAMPLE 2

A simple slotted-cylinder catalytic device of the present invention (of the type shown in Figure 2) was manufactured, cleaned, and its inside surface coated with the same amount and composition of coating and noble metals as in Example 1. The device had a length of 85 mm and a diameter of 30 mm. Its performance was evaluated using the same procedure as used in Example 1. Hydrocarbon plus nitrogen oxide and carbon monoxide emissions were measured to be 3.1 grams per km and 2.4 grams per km, respectively, versus uncontrolled emissions of 3.8 grams per km and 3.3 grams per km, respectively, determined by subjecting the same motorcycle to the same driving cycle.

EXAMPLE 3

A slotted-cylinder catalytic device of the present invention having a dual radial insert (of the type shown in Figure 4, view B) was manufactured, cleaned, and its inside surface coated with the same amount and composition of coating and noble metals as in Example 1. The device had a length of 90 mm and a diameter of 30 mm. Its performance was evaluated using the same procedure as used in Example 1. Hydrocarbon plus nitrogen oxide and carbon monoxide emissions were measured to be 2.0 grams per km and 1.9 grams per km, respectively, versus uncontrolled emissions of 3.8 grams per km and 3.3 grams per km, respectively, determined by subjecting the same motorcycle to the same driving cycle.

CLAIMS

1. A catalytic device suitable for treating exhaust gas from an internal combustion engine having an exhaust pipe, said pipe containing at least one straight section having an inner surface having a fixed radial dimension, comprising a structure having an interior surface and an outer surface which outer surface has a radial outside dimension greater than said straight section inner surface's fixed radial dimension, which radial outside dimension may be temporarily reduced by applying an external radial compressive force thereby permitting the structure to be inserted into said straight section, and which structure relaxes when the compressive force is removed thereby causing the structure's outer surface to contact the straight section inner surface thereby creating a friction force between the structure's outer surface and the straight section inner surface, which force acts to hold the structure coaxially inside the straight section and wherein said interior surface is at least partially coated with a catalytic material that is effective for treating said exhaust gas.

2. The catalytic device of Claim 1 wherein the straight section is round and the structure is a cylinder having a slot extending the cylinder's entire length.

3. The catalytic device of Claim 1 wherein the structure has an S-shaped cross section.

4. The catalytic device of Claim 1 wherein the straight section and the structure each have an oval cross section and the structure has a slot extending its entire length.

5. The catalytic device of Claim 1 wherein the structure contains at least one insert that provides additional surface area, said insert being fixedly connected to said structure's interior surface.

6. The catalytic device of Claim 1 wherein the structure contains at least one insert that provides additional surface area, said insert being fixedly connected to said structure's interior surface and being further characterized in that the insert contains perforations.

7. The catalytic device of Claim 1 wherein the structure is made of a metal selected from the group consisting of ferritic and austenitic stainless steels.

8. The catalytic device of Claim 1 made by a process comprising forming the structure from a steel selected from the class consisting of ferritic and austenitic steels, heating the structure, thereby driving off any oils or organic compounds that might remain on the structure after said forming and then applying the catalytic material by a method selected from the class consisting of a) dipping the structure into a solution of catalytic material and then wiping said outside surface clean and b) dipping the structure into a solution of catalytic material, allowing the solution to dry and then mechanically removing the dried solution from said outside surface.

9. A method for treating exhaust gas from an internal combustion engine having an exhaust pipe containing a straight section comprising inserting the catalytic device of Claim 1 into said straight section.

10. The method of Claim 9 wherein the engine is used to power a motor vehicle selected from the group consisting of motorcycles, automobiles, trucks, busses and tractors.

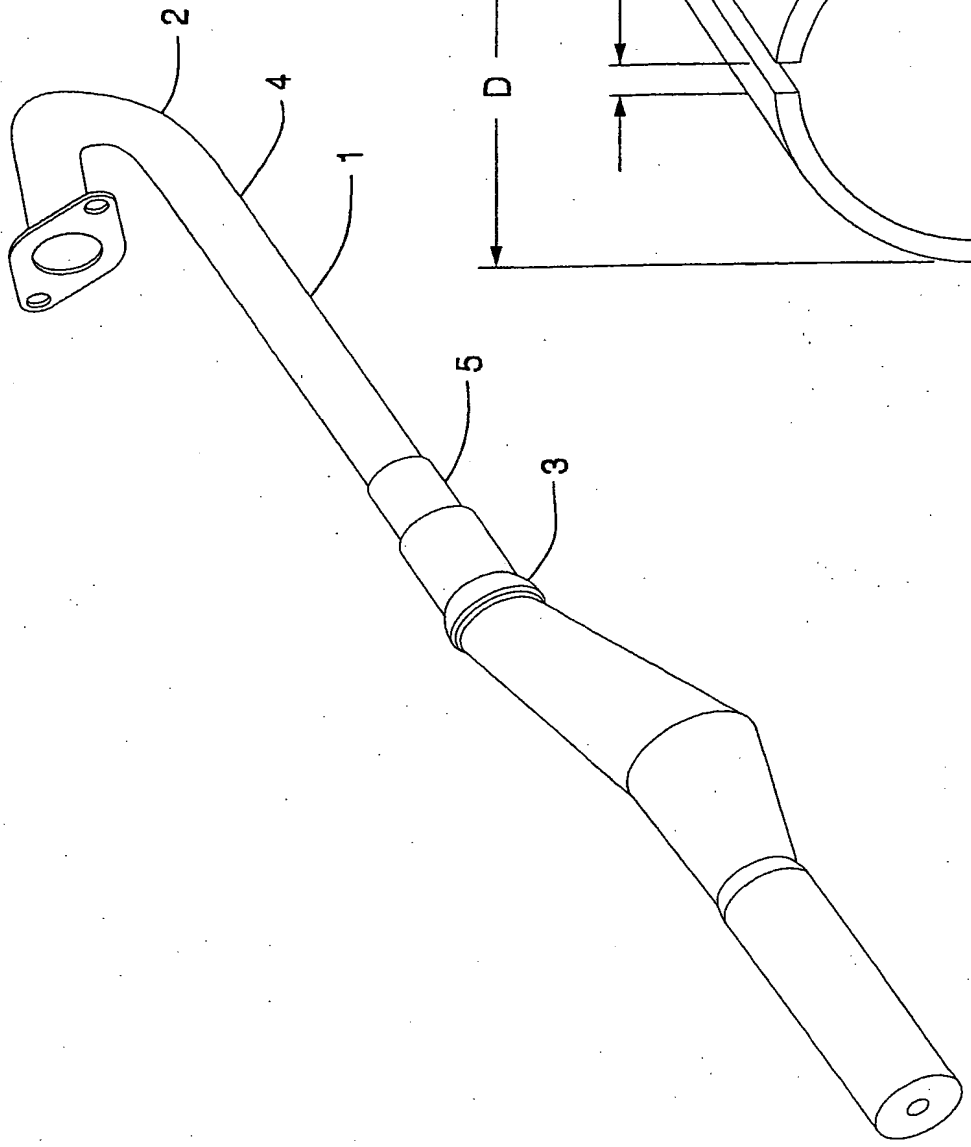

FIG. 1

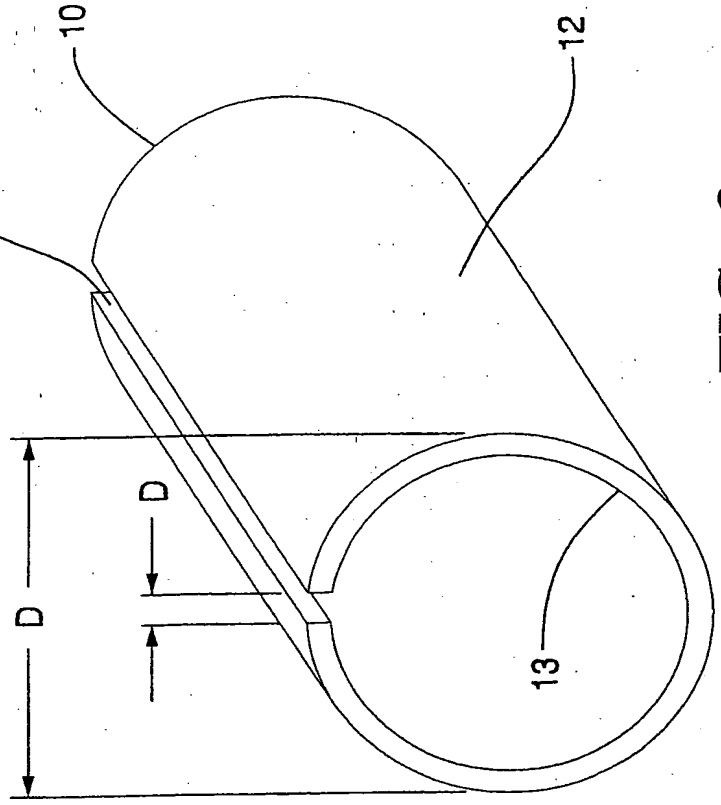

FIG. 2

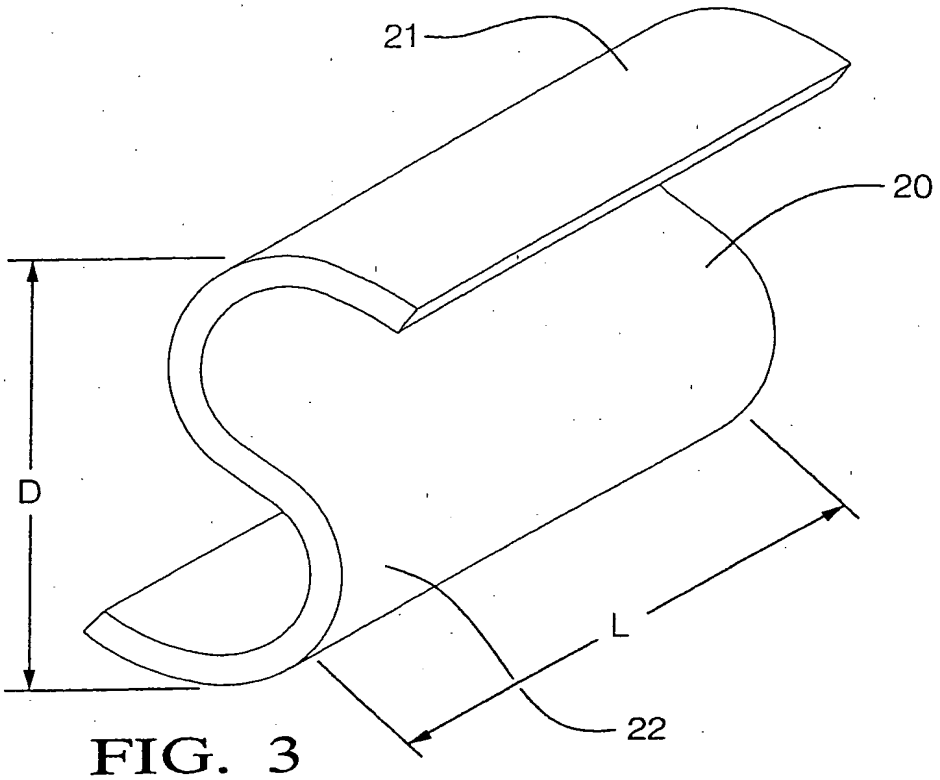

FIG. 3

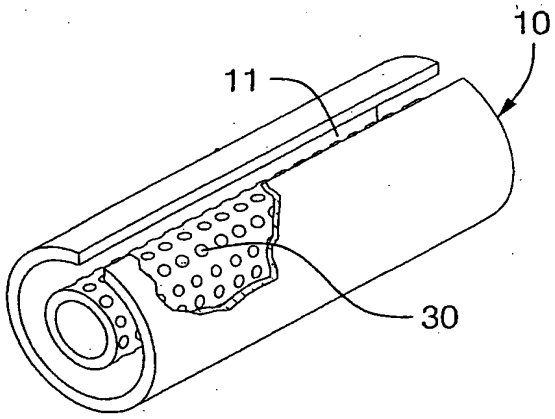

FIG. 4 A

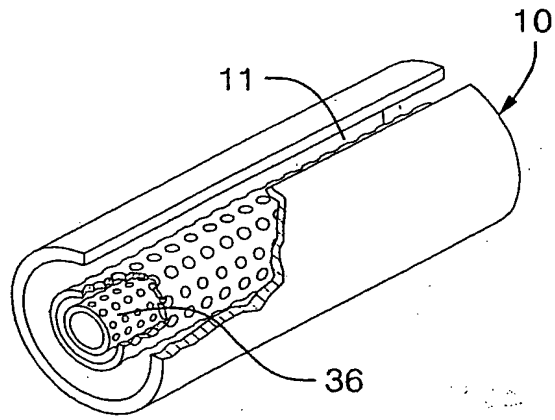

FIG. 4 B

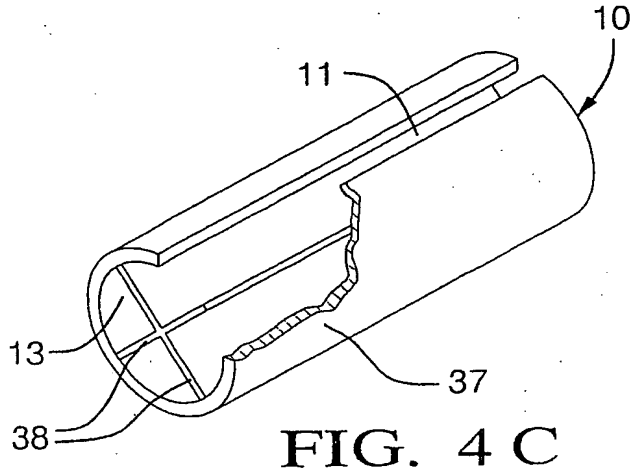

FIG. 4 C

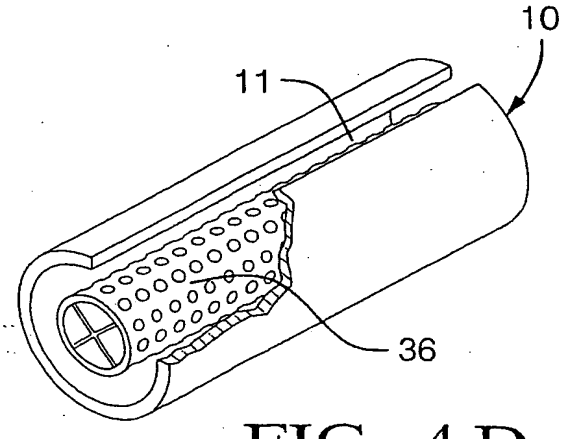

FIG. 4 D

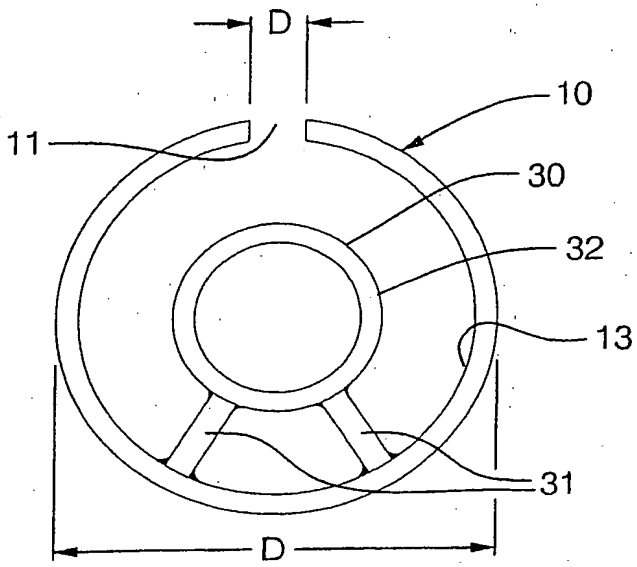

FIG. 5 A

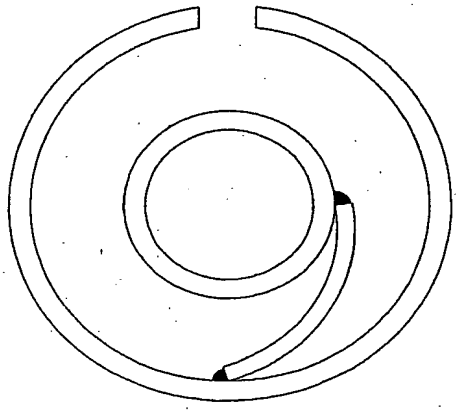

FIG. 5 B

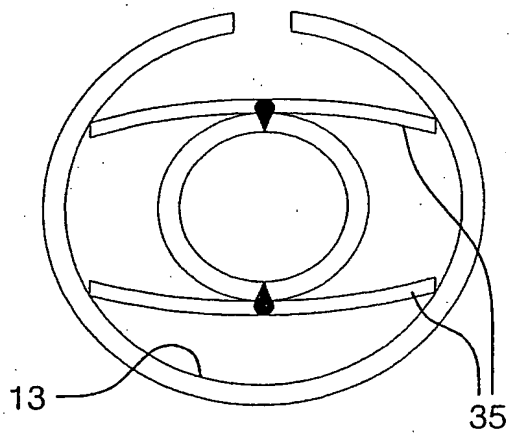

FIG. 5 C

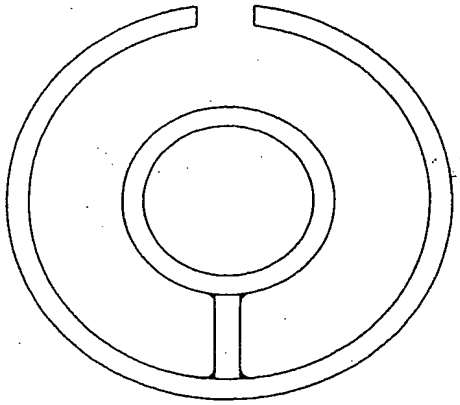

FIG. 5 D

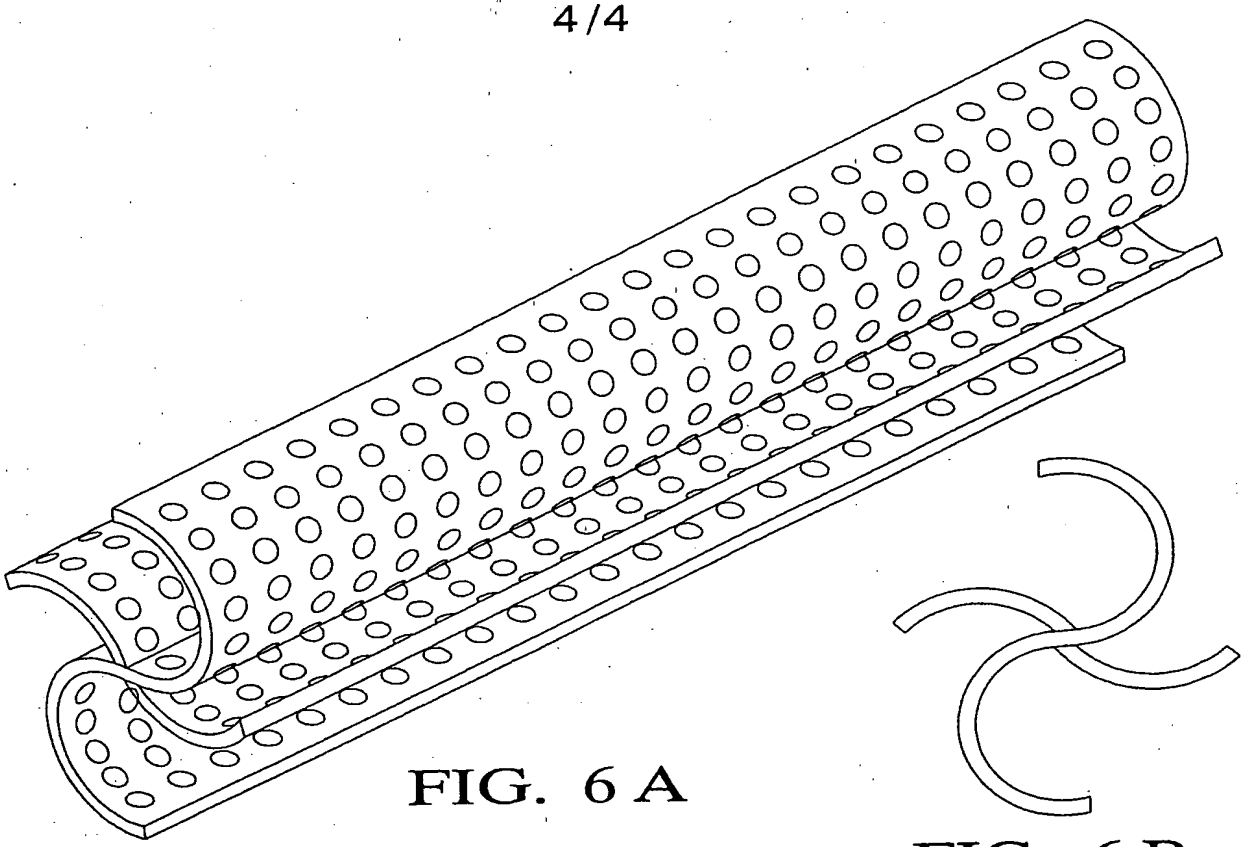

FIG. 6 A

FIG. 6 B

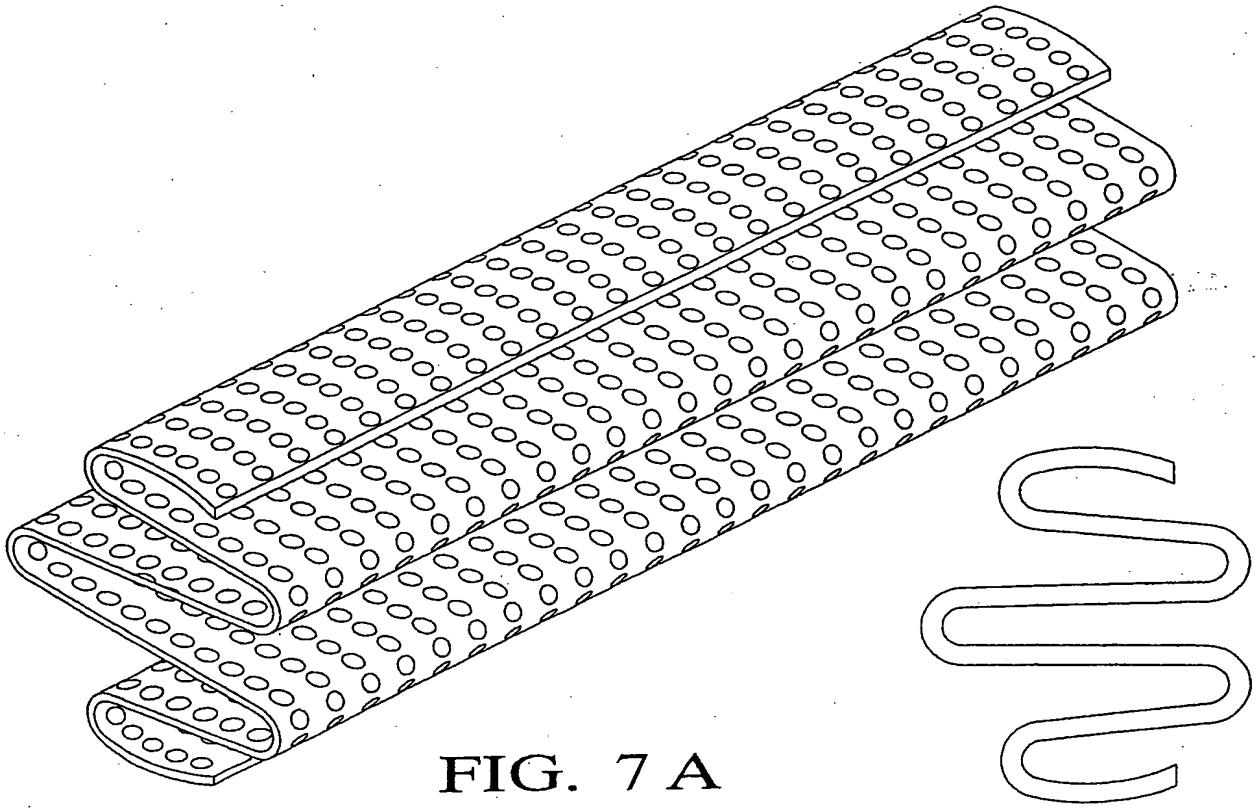

FIG. 7 A

FIG. 7 B

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 99/13178

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 F01N3/28

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 F01N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 095, no. 003, 28 April 1995 (1995-04-28) & JP 06 343876 A (YAMAHA MOTOR CO LTD), 20 December 1994 (1994-12-20)	1,3,5,6, 9,10
Y	abstract	2,4

Y	US 5 724 735 A (MONTALBANO ANDREW J ET AL) 10 March 1998 (1998-03-10) column 2, line 2 - line 35 column 3, line 37 -column 4, line 13 figures 3-5	2,4

A	EP 0 480 082 A (NIPPON STEEL CORP) 15 April 1992 (1992-04-15) page 3, column 54 -page 4, column 29 figures 1-5	1

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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22 September 1999	29/09/1999

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 99/13178

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